Amendments to the Drawings:

The attached sheets of drawings include changes to Figs. 1, 2, 3A, 3B, 4 and 5. In each of the amended figures, Applicant has inserted numerals to identify the elements in place of the text which previously appeared in the drawings. A legend appears on the annotated sheets showing the changes to the figures which provides the relationship between the text and the element numbers.

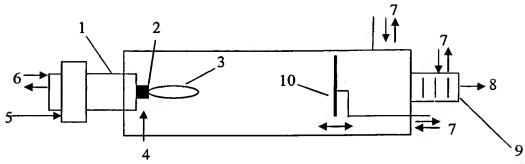
Attachment:	Replacement Sheets	**6 Figures on 5 Sheets**
	Annotated Sheets Showing Changes	**6 Figures on F Sheets**

Appendix

Appl.No. 10/535,050
Amendment Dated Jan. 28, 2009
Reply to Office action of Oct. 28, 2008
Replacement Sheets

Application No. 10/535,050
Amendment Dated Jan. 28, 2009
Reply to Office action of Oct. 28, 2008
Annotated Sheets Showing Changes

Figure 1



LEGEND CORRELATING TEXT DESCRIPTION TO ELEMENT NOS. for FIGS. 1 and 2

Element No.	Text Description
1	Plasma torch
2	Nozzle
3	Plasma jet
4	Carbon containing gas + carrier gas
5	Plasma forming gas
6	Cooling Water (C.W.) and electrical supply
7	C.W.
8	Gas exhaust to pump and cleaning system
9	Off-gas cooling system
10	Movable disk
11	Catalyst particles + carrier gas

Figure 2

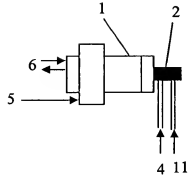
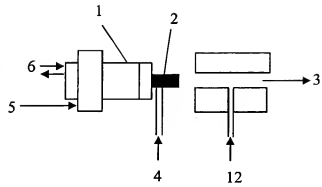


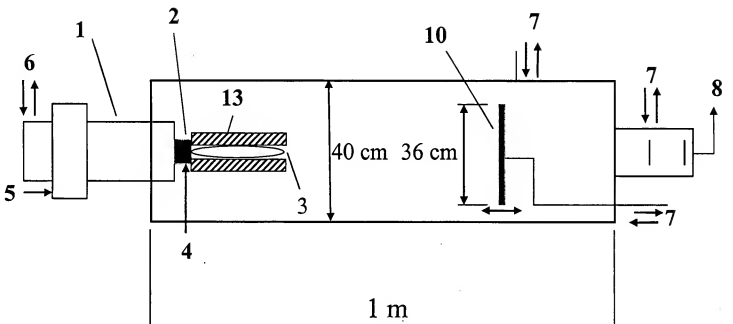
Figure 3A



LEGEND CORRELATING TEXT DESCRIPTION TO ELEMENT NOS. for FIG 3A

Element No.	Text Description
1	Plasma torch
2	Nozzle
3	Plasma jet
4	Carbon containing gas + carrier gas
5	Plasma forming gas
6	Cooling Water (C.W.) and electrical supply
12	Catalyst particles or solid metal pieces

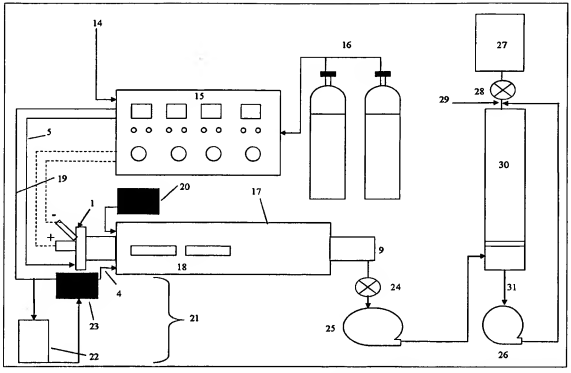
Figure 3B



LEGEND CORRELATING TEXT DESCRIPTION TO ELEMENT NOS. for FIG. 3B

Element No.	Text Description
1	Plasma torch
2	Nozzle
3	Plasma jet
4	Carbon containing gas + carrier gas
5	Plasma forming gas
6	Cooling Water (C.W.) and electrical supply
7	C.W.
8	Gas exhaust to pump and cleaning system
10	Movable disk
13	Graphite cylinder

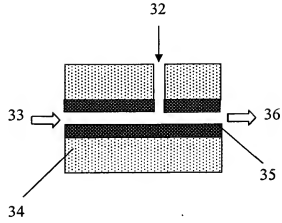
Figure 4



LEGEND CORRELATING TEXT DESCRIPTION TO ELEMENT NOS. for FIG. 4

Element No.	Text Description
1	Plasma torch
4	Carbon containing gas + carrier gas
5	Plasma forming gas
9	Off-gas cooling system
14	Water supply
15	Control panel
16	Gas cylinders (helium and argon)
17	Reactor chamber
18	Observation/spectroscopic windows
19	Carrier gas
20	Catalyst injection system
21	C_2Cl_4 injection system
22	Pressurized C_2Cl_4 Reservoir
23	Liquid vaporizer
24	Vacuum controlling valve
25	Vacuum pump
26	Recycle pump
27	Caustic supply
28	Control valve
29	Fresh water
30	Packed column
31	Drain

Figure 5



LEGEND CORRELATING TEXT DESCRIPTION TO ELEMENT NOS. for FIG 5

Element No.	Text Description
32	He carrier gas and gaseous C_2Cl_4 as carbon source
33	He plasma from arc discharge with tungsten vapour from erosion
34	Tungsten nozzle
35	CNT deposits
36	Plasma torch tailflame into reactor

REMARKS/ARGUMENTS

Applicant hereby requests an extension of one month under Rule 1.17(a) (1) for responding to the Office Action. The required fee of $65.00 is being submitted via the accompanying fee transmittal form. An assignment in favour of McGill University and a Power of Attorney in favour of the undersigned was filed by facsimile in respect of this application on February 11, 2009 and Notice of Acceptance was mailed February 20, 2009.

Information Disclosure Statement (IDS)

The examiner indicates that the first reference listed in Applicant's IDS of 03/30/2006 was not included when the IDS was filed, although it was listed as included and Applicant did provide it to Applicant's previous attorneys. Applicant suspects that the cover page of the reference and Table of Contents were not included although referenced in the description of the document in the IDS and this may not have allowed the Examiner to identify the reference in the materials filed with the IDS. In any event Applicant has filed herewith a further supplementary IDS which includes a fresh copy of the Boulos reference with all of the referenced pages and some additional pages that Applicant is relying on in this submission. Further, Applicant is submitting the required fee of $180 in respect of the Supplementary Information Disclosure Statement submitted herewith.

Election of Species

The examiner has objected to the claims for being directed to more than one species of the generic invention. The Examiner indicates that these species lack unity of invention because they are not so linked as to form a single general inventive concept under PCT Rule 13.1. The Examiner recites four species as follows:

(i) catalyst generated from droplets of metal generated from a metal sample
(ii) catalyst generated from metal vapour from metal evaporator
(iii) catalyst generated from metal vapour from nanoparticle generator
(iv) catalyst generated from nanoparticles of catalyst added to a liquid carbon precursor

The Examiner further indicates that Claim 1 is generic, but the species "do not relate to a single general inventive concept under PCT Rule 13.1 because, under PCT Rule 13.2, the species lack the same or corresponding special technical feature since each species has clearly different design and structure."

In a telephone call to Applicant's former attorneys, a provisional election was made with traverse to prosecute the invention of the catalyst generated from droplets of metal generated from a metal sample brought into contact with the flame, namely the subject matter of claim 14. While Applicant's would prefer to elect the species of claim 15, it is understood that the provisional election must be confirmed and this Applicant has done by retaining claim 14 and cancelling claims 15 to 18 as requested by the Examiner. However, this election is made with traverse. Applicant reserves the right to file divisional applications in respect of the subject matter of the cancelled claims in the event applicant's arguments regarding what Applicant believes to be an improper election requirement are not accepted by the Examiner when the generic claim is allowed. It should be noted that no change in inventorship is believed to be required in the context of this restriction.

Each of the species of Claims 14 to 17 represents alternative sources of catalysts and is linked by that precise technical feature. While the use of each of these species requires a process that reflects the selected "source of the catalyst", each is part of the same generic invention found in amended claim 1. They are technically linked as they perform the same function in the process which is to supply catalyst for the process. Further, these species do not

produce different products from those defined in the generic claims. For these reasons, Applicant would submit that if the generic claim 1 is granted, Applicant should be permitted to re-join the cancelled claims and retain all of the species in a single patent application.

In paragraph 7 of the Action, the Examiner indicates that restriction is required between product and process claims. Applicant is not certain of the meaning of this requirement as there are only process claims in the present application. While these claims define processes that produce products, the products all fall within the scope of claim 1, which in itself should not be a problem in the manner proposed by the Examiner. Clarification of this rejection is requested.

Amendments to the application

Claim 1 has been amended to indicate that the carbon containing gas (now substance) is injected via a fast quenching nozzle attached to a high enthalpy electrode-generated direct current thermal plasma torch. In addition Applicant has changed "carbon-containing gas" to "carbon containing substance" in Claims 1, 2, 6 and 11. A new Claim 22 has been added which defines the carbon substances.

As a result of the first amendment to claim 1, Claims 4 and 5 have been cancelled. In claim 1, some minor edits have been made to the claim to improve its clarity. Claims 15 to 18 have been cancelled as noted above. The dependencies of claims 6, 7 and 19 have been amended so that these claims refer to Claim 1. New claims 20 and 21 have been added which find support in the specification at page 4 lines 12 to 17.

Support for claim amendments

Support for the amendments to claim 1 and new claim 22 can be found in the following passages of the description:

In the "Summary of the invention" section of the specification:

In Paragraph [0008] the supporting passage reads:

> *"...A carbon-containing gas is used... This is much more economical from the energy perspective than the solid carbon sublimation used in the graphite arc and laser methods, and also adds to the scale up potential through the volumetric increase of gas treated at large power."*

In Paragraph [0008], the supporting passage reads:

> *"Alternatively, the catalyst nanoparticles can be transported into the* ***liquid hydrocarbon precursor... before injection either in a high power DC plasma torch...***"

In Paragraph {0011], the supporting passage reads:

> "*The carbon precursor... in TP-ICP systems can be injected directly in the TP-ICP torch in the liquid form through a probe without the need for prior vaporization of the carbon precursor... In such a case* ***the metal catalyst nanoparticles can be added and transported by the liquid carbon precursor and injected simultaneously in the torch plasma***."

In Paragraph [0026], there is the supporting passage:

> "*Alternatively, metal catalyst nanoparticles can be added in* ***the liquid carbon precursor and injected downstream of the plasma torch.***"

In Paragraph [0033], a final supporting passage reads:

> "***Higher power DC plasma torches... can provide the flexibility to inject the liquid TCE directly into the torch.*** *In such cases, nanoparticles of catalyst can also be incorporated into the liquid feed and simultaneously injected in the plasma."*

Applicant would submit that the above passages provide clear support for the amendment relating to the carbon substance terminology.

As indicated the Figures have been amended to replace the text in the drawings with element numbers, which was not the result of a rejection by the Examiner, but rather a desire to simplify the reading of the specification. The following is a legend that relates the element numbers to the text. These

element numbers have also been added to the text of the specification. And the following is a table that provides the correlation.

Element No.	Text in Drawings
1	Plasma Torch
2	Nozzle
3	Plasma Jet
4	Carbon Containing Gas + Carrier Gas
5	Plasma Forming Gas
6	Cooling Water (C.W.) and Electrical Supply
7	C.W.
8	Gas exhaust to pump and cleaning system
9	Off-gas cooling system
10	Movable Disk
11	Catalyst particles + Carrier Gas
12	Catalyst particles or solid metal pieces
13	Graphite cylinder
14	Water Supply
15	Control Panel
16	Gas Cylinders (Helium and Argon)
17	Reactor Chamber
18	Observation/spectroscopic windows
19	Carrier Gas
20	Catalyst Injection System
21	C_2Cl_4 Injection System
22	Pressurized C_2Cl_4 Reservoir
23	Liquid Vaporizer
24	Vacuum Controlling Valve
25	Vacuum Pump
26	Recycle Pump
27	Caustic Supply

Element No.	Text in Drawings
28	Control Valve
29	Fresh Water
30	Packed Column
31	Drain
32	He carrier gas and gaseous C_2Cl_4 as carbon source
33	He plasma from arc discharge with tungsten vapor from erosion
34	Tungsten nozzle
35	CNT deposits
36	Plasma torch tailflame into reactor

The change to Paragraph [0005] of the specification reflects the amendments made to Claim 1 submitted herewith.

No new matter has been added by way of these amendments.

Claim Rejections - 35 USC § 102

Rejection of Claims 1-3 under 35 U.S.C. 102(a) as being anticipated by Smiljanic *et al.* (Chem. Phys. Lett. 356, 2002, 189-193).

The Examiner will appreciate that amended claim 1 as indicated above now incorporates the subject matter of cancelled claims 4 and 5. As a result the claimed process now requires that the carbon containing gas is injected via a fast quenching nozzle attached to a high enthalpy electrode-generated direct current thermal plasma torch. Since the Examiner himself has appreciated that this addition provides a process that is not found in the cited reference, the amended claims are not anticipated by the reference. Therefore, as the Examiner's rejection no longer applies, Applicant respectfully submits that it should be withdrawn. Applicant would submit that the amendment whereby the term "carbon-containing gas" has been replaced with "carbon-containing substance" does not affect this rejection.

Before dealing with the remaining claim rejections, Applicant would submit that some explanation of plasma torch terminology by way of background may be helpful. This terminology, as accepted in the research community, relates to a plasma generating device from which a jet of plasma having specific physical/chemical properties is generated, this plasma jet being used downstream for post treatment. Plasma torch devices typically try to maintain the plasma generation zone as much as possible independent and not affected by the processing being performed in the plasma jet downstream of the plasma generation. This is the case in electrode based DC (direct current) thermal plasma torch systems where the gas/droplets/particles being treated are effectively injected downstream of the plasma generation zone based on an electric arc between the electrodes.

The "microwave plasma torch" as described in the cited Smiljanic paper is using an injection of the gases to be treated **directly within the plasma generation zone** (zone of strong electromagnetic radiation), a geometry which strongly affects the physical/chemical characteristics of this zone. As such, **these systems are usually labeled in the literature using the following terminology: "*micro-wave plasma reactors*", "*microwave-sustained plasma columns*", "*traveling wave discharges*", "*surface wave-sustained discharges*", and NOT using the "*plasma torch*" terminology** (see for example M.D. Calzada, M. Moisan, A. Gamero, A. Sola, Experimental investigation and characterization of the departure from local thermodynamic equilibrium along a surface-wave-sustained discharge at atmospheric pressure, J. Appl. Phys., 80, 1, 1996 and US Patent Number 6,224,836 related to the same source as used by Smiljanic et al). Such geometry is certainly not obvious to transfer into another plasma system. In fact, one would like to avoid the use of this type of geometry in industrial production devices aiming for large quantities of bulk material production.

In the case of ICP (inductively coupled plasmas) plasmas, the injection is made in the plasma generation zone. However in the "*ICP thermal plasma torch*" (i.e. where the "*plasma torch*" terminology is effectively used), care is taken to minimize the impact and perturbations on the plasma generation zone by keeping a small ratio of the generator energy absorbed by the gas/droplets/particles being treated. This can only be accomplished when operating the ICP thermal plasma torch at relatively high powers, i.e. typically above ~10 kW. **Such powers are not attained in atmospheric pressure microwave plasma discharges**. The microwave source used in the cited Smiljanic paper [1] has a power of 1.3 kW.

As stated above, one important difference between the two systems is the real and complete decoupling of the plasma generation zone from the plasma treatment and synthesis zone in the DC thermal plasma torch. The torch operation is independent from the process gases, unlike the microwave reactor. A second important difference is related to the high energy density available downstream of the thermal plasma torch which makes the full processing possible; in contrast, the microwave system used in the Smiljanic paper [1] uses the microwave "*quartz tube placed inside a tubular furnace whose temperature is maintained at 1300 K in order to prevent an excessively large temperature gradient at the outlet of the torch, which could lead to the formation of amorphous carbon*". The full temperature profile in the DC thermal plasma torch is controlled by the torch itself, from the strong quench zone generating the catalyst nanoparticles, down to the constant high (above the 1000 K range) temperature zone for nanotube growth downstream of the catalyst formation.

Turning now to the rejections of the claims raised by the Examiner, the following comments are submitted.

Claim Rejections - 35 USC § 103

Claims 4-7 and 11-12 are rejected under 35 U.S.C. 103(a) as being unpatentable over by Smiljanic *et al.* (Chem. Phys. Lett. 356, 2002, 189-193) in view of Tsantrizos *et al.* (US Patent No. 5,395,496), hereafter Tsantrizos #1.

As the Examiner has recognized, **Similjanic *et al.*** does not explicitly teach using a high enthalpy plasma torch with a nozzle to produce the plasma used in carbon nanotube (CNT) production.

The Examiner further states that Tsantrizos #1 teaches the synthesis of fullerenes (CNT) in using a high enthalpy non-transferred d.c. plasma torch or an induction plasma torch as the plasma generating device.

The Examiner then argues that it would have been obvious to a person of skill in the art at the time of the invention to substitute a "high enthalpy non-transferred d.c. plasma torch or an induction plasma torch as the plasma generating device" for the production of fullerenes as taught by Tsantrizos #1 for Similjanic et al's atmospheric plasma jet. The motivation to do so would have been that both devices generate a plasma and operate at comparable temperatures.

The examiner goes on to say that fullerenes as defined by Tsantrizos #1 are "hollow molecules made up of curled-up graphitic sheets", simply CNT, as claimed in Claims 4 and 5 (now found in amended claim **1**). For Claim 6, the Examiner states that Tsantrizos #1 teaches that "the inert plasma forming gas is preferably helium and the carbon and halogen containing gas is preferably a carbon halide gas such as $CBrF_3$ or C_2Cl_4, where the tetrachloroethylene is the carbon containing gas.

The Examiner states regarding claim 7, that although Smiljanic *et al.* fails to teach that the metal electrode generates the metal vapor in the plasma torch, the same type of plasma is used in Tsantrizos #1 and thus it would be obvious that metal vapor or particles would also be ejected from such an electrode in the

same type of plasma torch due to the high temperatures produced by the torch although not expressly stated.

Dealing first with the rejection of claims 4 to 7, Applicant would submit that given the amendments to the claims, Applicant will consider this rejection in the context of amended claims 1, 2 and 3, as well as claims 5 and 6.

Applicant would respectfully submit that the Examiner's characterization of the prior art is not correct. In the case of the Smiljanic *et al.* reference, there is disclosed the fabrication of single wall carbon nanotubes using **a microwave plasma reactor** coupled to a furnace maintained at 1300° K, and having the carbon (ethylene) and catalyst (vaporized ferrocene) precursors injected in a vapor form into the microwave plasma.

In the case of Tsantrizos #1, there is disclosed the use of a DC thermal plasma torch for the homogeneous nucleation process of the fullerene molecules (C_{60} and C_{70}). There are four main differences to note regarding the teachings of Tsantrizos #1 and the presently claimed invention.

1. Tsantrizos #1 teaches the means to form fullerenes through a *homogeneous* reaction path using a thermal plasma, while the present claims define the means to form carbon nanotubes through a *heterogeneous* reaction path using a thermal plasma. The *homogeneous* reaction path provides the fullerene molecule formation directly from the raw carbon atoms/molecules present in the gaseous plasma stream in a one-step process. The *heterogeneous* path consists of reactions involving a solid or a liquid catalyst surface that needs to be in the scale size of nanoparticles being dispersed in the gaseous plasma state, this involves a complex two-step process. The first step requires setting the proper physical and chemical conditions to nucleate the nanoparticles of catalyst of a proper metallic material and size range.

   This metallic nanoparticle nucleation step is not required in the process of the citations for generating fullerenes; furthermore, **such**

nanoparticle nucleation having the proper size range forms a complex and challenging task in terms of the control of the plasma stream properties. The means for generating these nanoparticles are not provided in the cited art, which leads to fullerene molecules and no possibility for the one-dimensional tubular structures of carbon nanotubes as are provided by the present process.

The nanoparticles of metal catalyst generated in the presently claimed process further need to be transported into a plasma zone containing the proper carbon chemical species and the proper temperature profile for the second step to occur. The second step involves the charging of the metal catalyst nanoparticles with carbon and allowing the growth of nanotubes at their surface under a temperature and residence time regime different from the conditions needed in the first step, and again different from the chemical "soup" at the origin of the fullerene synthesis chemical reaction.

The cited art does not teach a heterogeneous reaction process and does not provide evidence that carbon structures based on such a heterogeneous route are produced. In view of the difficulty of transforming a direct homogeneous chemical reaction into a controlled 2-step heterogeneous reaction path of large complexity and control, the presently claimed process provides a patentable advance over the prior art which cannot be considered obvious. The complex chemical and physical steps in the formation of these two molecular structures (fullerene and carbon nanotubes) are totally different both chemically and physically.

2. Both the cited art and the presently claimed process use a DC thermal plasma torch as the means to produce the plasma. The present specification in fact makes reference to the Tsantrizos patents as the plasma source. However, the presently claimed process provides the means for the generation of metal vapors acting as catalyst precursors in

the plasma stream. Metal precursors are either produced inside the torch using various electrodes, or introduced in the nozzle of the plasma torch.

3. Fullerene synthesis in Tsantrizos #1 involves the formation of a large and uniform plasma volume downstream of the thermal plasma torch in order to maintain the carbon precursor species with enough residence time in conditions leading to fullerene molecule formation. In contrast, the present process provides the conditions needed for the metal precursors to form nanometer scale metal catalyst particles through the use of strong quenching rates such as a supersonic shock being created in the nozzle or downstream of the nozzle. The flow and thermal evolutions in the two streams are opposite: uniformity requirement in fullerene synthesis, and very strong and rapid cooling rates in carbon nanotube synthesis.

4. Following the formation of the nanoparticle in the present process, the means are provided to maintain this nanoparticle within a high enough temperature so that carbon is present in a non-solid form and diffuses in the particles maintained in the liquid state. The means provided in the present process provide this downstream control of the region of nanoparticle loading around specific temperatures for metal-nanotube segregation. No such means are described in the citations.

Given all of these differences, Applicant would submit that the combined teachings of Smiljanic *et al.* and Tsantrizos #1 would not lead the person skilled in the art to the presently claimed process as defined in claims 1 to 3, 6, 7, 11 and 12. There is no motivation to make the substitution proposed given the significant differences discussed above. For these reasons, Applicant believes this rejection should be withdrawn.

Further, in Applicant's submission, the Examiner's rejection on the ground of obviousness cannot be sustained by a mere conclusionary statement. There is no articulated reasoning (based on Applicant's submission on how the person skilled in the art would interpret the cited references) that provides the rational

underpinning to support the legal conclusion of obviousness (See In re: Hahn, 4111F.3d 977, 988 (CA Fed. 2006) cited with approval in KSR).

Claims 8-10 and 19 are rejected under U.S.C. 103(a) as being unpatentable over Smiljanic *et al.* (*Chem. Phys. Lett.*, 356, 2002, 189-193) in view of Tsantrizos *et al.* (US Patent No. 5,395,496) as applied to claims 4-7 and 11-12 above and further in view of Tsantrizos *et al.* (US Patent No. 5,147,998), Tsantrizos #2.

The Examiner states:

> "Regarding applicant's claims 8-10 and 19, neither Smiljanic nor Tsantrizos #1 teach the specific materials of construction for the electrode. However, the same type of plasma used by Tsantrizos #1 is described in detail by Tsantrizos #2. Tsantrizos #2 states the main feature of their invention is the copper electrodes attached by high temperature soldering, this making it possible to use a much wider range of electrode materials including thoriated tungsten (column 3, lines 44-50). Claim 19 is described by Tsantrizos #2 on column 2, lines 42-52. The refractory electrode material could be a ceramic. The water-cooling system is also described therein."

Applicant would respectfully submit that the Examiner's analysis of the cited references is not accurate. The person skilled in the art would understand that Tsantrizos teaches the use of various electrode materials for torch operation purposes only, while claims 8-10 in the present application provide a series of electrode materials acting as source materials of metal vapor for the nanoparticle catalyst nucleation, this being the first step of the heterogeneous nucleation process. The electrode erosion is used in the present claims as a source of precursor material, and the electrode material fulfills a new added role from Tsantrizos #1 and #2. This source of precursor material has to be present in the present invention as claimed. This also provides an inventive step with respect

to Smiljanic since **no** solid material providing metal vapor can be introduced in the Smiljanic microwave apparatus; only gaseous feed is possible with consequences on the purity of the feedstock and availability of some materials.

For these reasons, Applicant would submit that claims 1 to 3, 6, 7, 11 and 12 are directed to patentable subject matter that is not obvious from the references in the combinations proposed by the Examiner. Applicant would respectfully submit that the combination of teachings of the citations, when clearly understood, could not lead to the present invention as claimed, since Smiljanic's microwave apparatus cannot accommodate solid material to provide metal vapor. Thus the combination proposed by the Examiner is impossible to achieve. Applicant respectfully requests that this rejection be withdrawn.

Claims 13 and 14 are rejected under 35 U.S.C. 103(a) as being unpatentable over Smiljanic *et al.* (*Chem. Phys. Lett.*, 356, 2002, 189-193) in view of Cohen *et al.* (US Patent No. 5,993,697).

The Examiner states:"As stated above, Smiljanic teaches making SWNT in a plasma torch with a carbon-containing gas and with catalysts formed *in situ* disclosing what is recited in applicant's claim 1. Smiljanic does not teach injecting at least one metal powder into the outlet flame of the torch. Cohen teaches making metallic carbon materials or CNT in a plasma where catalytic particles, such as transitions metals, in powder or other form can be injected directly into the arc or with the carbon feedstock (column 14, lines 12-15). Therefore, it would have been obvious to one of ordinary skill in the art at the time of the invention that a catalyst is needed to grow nanostructures regardless of whether the catalyst was added together with the carbon-containing gas (as the case with Smiljanic) or after in the flame in a variety of forms as long as both the carbon source and catalyst are present together. Introducing the metal catalyst directly into the plasma is useful to produce metallic carbon nanostructures (Cohen abstract)."

With regard to claim 13, Applicant would note that on the contrary, it is **not** something obvious to have the catalyst "**in the proper form**" for the formation of carbon nanotubes. In particular, the sentence above indicating that "*regardless of whether the catalyst was… as long as both the carbon source and catalyst are present together*" is not true. The catalyst needs to be in a specific morphology in order to play its role in this particular heterogeneous reaction pathway. For example, a catalyst present in a vapor form within the carbon nanotube growth zone (defined by local carbon concentration and local temperature) **would not** generate carbon nanotubes. Similarly, a catalyst in the form of "big" solid or liquid metal particles in any range above 50 nanometers ($50x10^{-9}$ meters) **would not** generate carbon nanotubes. The reason is simple; the catalyst action here is to form a carbon nanotube in a **template** fashion. Only when the catalyst particles are in a size range between a few nanometers (~$5x10^{-9}$ m) up to roughly 40 nanometers ($40x10^{-9}$ m) will the carbon extracted from the metal-carbon mixture generate a tubular carbon structure with the particle at one end of the tube. This tube extraction from the nanoparticle typically occurs at a specific phase change condition called the eutectic point. To achieve a system providing the proper morphology of the catalyst within the proper growth zone is not obvious to one of ordinary skill in the art. Furthermore, the present process indicates (See Claim 13) that the thermal and flow regimes at the outlet of the plasma torch are able to provide the conditions needed to **vaporize** metal powder precursors injected in the thermal plasma torch tailflame, then nucleate nanoparticles with the proper size range downstream of the tailflame using the metal vapor generated, while maintaining the carbon vapor concentration and temperature regime required to load the nucleated nanoparticles with carbon at the eutectic phase change conditions. The above conditions can be achieved and controlled in the present process. However, these conditions are not possible to achieve in the microwave system of Smiljanic. A person skilled in the art would rule out any solid precursor catalyst injection possibility in the case of Smiljanic for these

reasons. Thus, it is clear that the rejection framed by the Examiner is incorrect and would not be apparent to a person skilled in the art as the combination would be rejected out of hand as being unworkable.

Turning now to the rejection of claim 14, experiments related to Claim 14 are found in the specification (Paragraph [0041] and Figure 14 a, b, and c). From the above discussion, neither the Smiljanic paper nor the Cohen patent teaches the possibility of inserting a metal sample (such as a wire in the demonstration experiment leading to Figure 14) for producing liquid droplets. These liquid droplets upon projection on a surface within the plasma stream provide the local conditions (carbon concentration and temperature) for carbon nanotube growth on its surface. Melting and droplet projection are not attainable in the outlet flame of the microwave plasma in Smiljanic, the temperature and flow cannot produce such conditions. Furthermore, supposing an additional source of heat and gas flow were added to Smiljanic, the carbon vapor conditions for nanotube generation would not be attained outside of the plasma system. The present process provides the necessary conditions for carbon nanotubes to be produced far from the thermal plasma torch in a plasma spray type configuration. This is counterintuitive with respect to Smiljanic, while Cohen is irrelevant to this sort of phenomena. A person with ordinary skill in the art would conclude a process such as Claim 14 would be impossible using the information provided in Smiljanic. Once again, there is no "rational underpinning" for the proposed combination, since the person skilled in the art would never propose such an unworkable combination.

When one examines the differences between the disclosures of the cited references and those of the amended claims, one notes the following with respect to the Smiljanic et al. paper (*Chem. Phys. Lett.* 356, 2002, 189-193):

(i) Smiljanic applies to a low power non-equilibrium (commonly called non-thermal) microwave plasma device which is not scalable in power and flow rates for industrial scale massive production. The claims in the present application as

amended apply to a DC thermal plasma torch device at an industrial power scale with very high flow rate throughputs. The thermal plasma torch device is readily scalable to the largest production powers (multi mega-watts) available using plasma systems. The present invention as claimed, teaches the means for large scale production while Smiljanic provides the means for small scale production with no scale up potential.

(ii) Smiljanic applies to an electrode-less device with no possibility of generating the metal vapor catalyst precursor directly inside the device. The present invention as defined by the amended claims involves internal electrodes providing the means to generate the metal vapor directly inside the plasma.

(iii) Smiljanic applies to the formation of single-walled carbon nanotubes, while the claims in the present application provide for the production of single-walled carbon nanotubes, multi-walled carbon nanotubes and nano-onions.

(iv) Smiljanic involves the use of a furnace heated at 1300 K at the outlet of the plasma device in order to provide the necessary heat load and residence time scale of the precursor species in a hot zone. The presently claimed process provides the means to generate the product without any additional heating device, the DC thermal plasma torch providing the necessary thermal and residence time conditions for the synthesis. This point again highlights the scale up limitations of a microwave plasma system.

(v) Smiljanic applies to the 2-temperature (non-thermal) plasma chemistry and physical conditions that can be generated inside a microwave plasma device limited in gas flow and plasma temperature values. The present claims apply to the thermal plasma chemistry and physical conditions generated in a DC thermal plasma torch. The different chemistry and physical conditions in the present process make use of (a) new chemical species and reaction path that cannot be produced in the low power microwave device, (b) strong gas flow generating a supersonic shock for the making of the catalyst nanoparticles of any metal precursor, including as an example tungsten which is used in the examples found

in the specification. Both supersonic shocks and a tungsten precursor cannot be used as a means of catalyst generation in carbon nanotube production using a microwave plasma device.

(vi) Smiljanic uses a gaseous precursor (carbon and metal vapor) injection scheme in the plasma device. The process of the present application as claimed is not limited to gaseous precursors; it also provides the means for liquid and solid precursors. An example of the use of a solid precursor is demonstrated in the specification (relative to Figure 14) and as claimed in Claim 14. The use of a gaseous precursor in Smiljanic is mandatory as the prior art plasma device cannot sustain liquid or solid feed.

Cohen teaches the use of metal catalyst in the atomic scale (gaseous state) reacting with carbon atoms on the graphene sheets in order to transform hexagonally bounded carbon (graphite sheet) into pentagonal and heptagonal bonding structures. Cohen **does not teach** the use of a nanoparticle of specific size between 5-40 nm to act as a catalytic **template** to form the tubular structure of carbon nanotubes. One can definitely **not** say that it is obvious for a person of ordinary skill in the art to transform the teaching of Cohen into a template driven process using a series of controlled sequential steps.

The present application teaches the possibility of inserting a metal sample (such as a wire in the demonstration experiment leading to Figure 14) for producing liquid droplets, this liquid droplet upon projection on a surface within the plasma stream providing the local conditions (carbon concentration and temperature) for carbon nanotube growth on its surface. Melting and droplet projection are not attainable in the outlet flame of the microwave plasma in Smiljanic, the temperature and flow cannot produce such conditions. Furthermore, supposing an additional source of heat and gas flow were added to Smiljanic, the carbon vapor conditions for nanotube generation would not be attained outside of the plasma system. The present process provides the necessary conditions for carbon nanotubes to be attained far from the thermal

plasma torch in a plasma spray type of configuration. This is counterintuitive with respect to Smiljanic, while Cohen is irrelevant to this sort of phenomena. A person with ordinary skill in the art would conclude a process such as Claim 14 would be impossible to achieve using the information provided in Smiljanic.

Thus Applicant would submit that the motivation to combine the teachings of Smiljanic and Tsantrizos #1, or #1 and #2, or Smiljanic et al with Cohen is non-existent as the combination does not suggest, let alone result in the process as claimed in the amended claims.

In summary, none of the Examiner's rejections based on obviousness are well founded as the Examiner has not understood or misinterpreted the teachings of the cited prior art. The combinations are fundamentally flawed and the flaws are clearly apparent to the person skilled in the art, since the Smiljanic reference upon which the Examiner builds his rejections cannot employ the present technology, because it will not work.

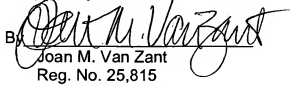
In Applicant's respectful submission, the rejections do not meet the factual inquiries set forth in Graham v. John Deere for the following four reasons:

1. The scope and contents of the cited art have not been correctly understood by the Examiner since microwave systems cannot function in the same way as the system of the present invention.
2. There are fundamental differences between the cited art and the invention as presently claimed that clearly indicate that the technologies are not interchangeable, let alone workable if that were done.
3. The level of ordinary skill in the art readily allows the skilled person to recognize the impracticality of the combined teachings.
4. The objective evidence in the present application is such that the differences between the claimed invention and the cited art are fundamental and do provide patentably distinct subject matter that is not obvious (inferable or suggested) from the cited art.

For all of these reasons the Examiner's obviousness rejections cannot be sustained against the amended claims and in Applicant's respectful submission, the rejections should be withdrawn.

Applicant respectfully requests that a Notice of Allowance be issued in this application.

Respectfully submitted,

By 

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